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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

UTILITY PATENT
APPLICATION TRANSMITTAL LETTER

Asst. Commissioner for Patents
Box Patent Application
Washington, D.C. 20231

Sir:

Enclosed for filing is an [X] original patent application or, [ ] a continuation-in-part patent application, by inventor(s) Cheuk W. Ko, entitled METHOD AND APPARATUS FOR CONTENT-BASED INTRUSION DETECTION USING AN AGILE KERNEL-BASED AUDITOR.

No. of pages in Application: 20 ; No. of Claims: 27 .

No. of Sheets of Drawings: Formal: 3 , Informal: 0 .

Also enclosed are:

[ ] a claim for foreign priority under 35 U.S.C. §§ 119 and/or 365 in
[ ] a separate document [ ] the declaration;

[ ] a certified copy of the priority document;

[ ] an Associate Power of Attorney;

[ ] ___ verified statement(s) claiming small entity status;

[X] a Combined Declaration and Power of Attorney of the inventors(s);

[ ] a signed Combined Declaration and Power of Attorney of the inventors will follow;

[X] an Assignment document and form PTO-1595;

[ ] a Power of Attorney by Assignee; and

[ ] Information Disclosure Statement and Form PTO-1449.

The fee has been calculated as follows:

CLAIMS					
	NO. OF CLAIMS		EXTRA CLAIMS	RATE	FEE
Basic Application Fee					$690.00
Total Claims	27	MINUS 20 =	7	$18.00=	$126.00
Independent Claims	3	MINUS 3 =	0	$78.00=	$0.00
If multiple dependent claims are presented, add $260.00					0
Total Application Fee					$816.00
If verified statement claiming small entity status is enclosed, subtract 50% of Total Application Fee					
Add Recording Fee of $40.00 if Assignment document is enclosed					$40.00
TOTAL APPLICATION FEE DUE					$856.00

[X] A check in the amount of $ 856.00 is enclosed.

[ ] Application fee will follow with missing parts.

[X] Please deduct any underpayments or credit any overpayments to Deposit Account Number 50-1003.

Please direct all correspondence concerning the above-identified application to the following address:

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Respectfully submitted,

By _____
A. Richard Park
Registration No. 41,241

Date: June 13, 2000

"Express Mail" Mailing Label No. **EL436467612US**

PATENT APPLICATION
ATTORNEY DOCKET NO. NA00-02401

METHOD AND APPARATUS FOR CONTENT-BASED INTRUSION DETECTION USING AN AGILE KERNEL-BASED AUDITOR

Inventor: Cheuk W. Ko

GOVERNMENT LICENSE RIGHTS

This invention was made with United States Government support under contract #F30602-96-C-0333 funded by the Defense Advanced Research Projects Agency (DARPA) through Rome Labs. The United States Government has certain rights in the invention.

BACKGROUND

Field of the Invention

The present invention relates computer security and intrusion detection systems. More specifically, the present invention relates to a method and an

apparatus for providing content-based intrusion detection using an agile kernel-based auditor.

Related Art

As computers become increasingly more interconnected, it is becoming progressively harder to safeguard computer systems from attacks launched across computer networks. Several types of attacks, such as buffer overflow attacks, and attacks that make unauthorized modifications to data objects, can be detected by examining data that is being read to and/or written from security critical files or network connections.

Unfortunately, existing intrusion detection systems cannot reliably detect these types of attacks because they do not possess the ability to examine data that is being read or written during system calls.

For example, an existing auditing system may record system call parameters or attributes of subjects and objects involved in the system calls. However, existing auditing systems do not record data that is being read from or written to files or network connections because the volume of data that is read or written is prohibitively large.

Some network sniffers can collect data being read from and/or written to files across a network. However, network sniffers cannot gather information regarding accesses to local files. Furthermore, network sniffers can suffer performance and packet-loss problems if they try to collect this type of data because as mentioned previously the volume is prohibitively large. Also, encryption is increasingly being used to protect the privacy of data transmitted across networks. Consequently, network sniffers will eventually be unable to obtain useful audit data.

Hence, what is needed is a method and apparatus for monitoring systems calls that gathers read and/or write data for intrusion detection purposes without encountering problems in handling large volumes of data.

Another problem is that existing auditing systems are not configured to collect information for specific intrusion detection systems. Existing auditing systems are typically developed by operating system developers, who do not necessarily know what types of data are required by intrusion detection systems. Consequently, existing auditing systems are not configured to gather parameters and/or other attributes that are required by an intrusion detection system. Furthermore, an intrusion detection system may require different types of data to be gathered at different times.

Hence, what is needed is a method and an apparatus that can be configured to selectively gather specific system call information for an intrusion detection system.

SUMMARY

One embodiment of the present invention provides content-based intrusion detection for a computer system by using an agile kernel-based auditing system. This auditing system operates by receiving an audit specification that specifies target attributes to be recorded during an auditing process. The audit specification also specifies an auditing criterion that triggers recording of the target attributes. Upon receiving the audit specification, the auditing system is configured to record the target attributes during system calls whenever the auditing criterion is satisfied. Next, an application program is monitored by the auditing system to produce an audit log containing the recorded target attributes. This audit log is examined in order to detect patterns for intrusion detection purposes.

In one embodiment of the present invention, configuring the auditing system involves compiling the audit specification to produce a kernel module, and then loading the kernel module into a kernel of an operating system. It also involves linking code from within the kernel module into system calls within the operating system.

In one embodiment of the present invention, in response to detecting an event during the auditing process, the system dynamically adjusts the auditing system to change the auditing criterion and/or the target attributes for subsequent operation of the auditing system.

In one embodiment of the present invention, the auditing system is configured to modify a system call jump table to cause selected system calls to execute code that causes the target attributes to be recorded in response to the auditing criterion being satisfied.

In one embodiment of the present invention, the target attributes can include: an argument from a system call; a parameter of a process making the system call; data read during the system call; data written during the system call; a parameter of a file involved in the system call; and a parameter relating to a network communication involved in the system call.

In one embodiment of the present invention, the auditing criterion can include: a user identifier for a process that is making a system call; an identifier for an application program from which the system call is being made; and an identifier for a file being accessed by the system call.

In one embodiment of the present invention, producing the audit log involves filtering the target attributes to reduce an amount of data stored in the audit log.

In one embodiment of the present invention, producing the audit log involves determining a characteristic of a target attribute, and recording the characteristic in the audit log.

In one embodiment of the present invention, the audit specification is received from either a user of the auditing system, or an intrusion detection mechanism.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 illustrates a computer system in accordance with an embodiment of the present invention.

FIG. 2 illustrates the process if configuring an auditing system in accordance with an embodiment of the present invention.

FIG. 3 illustrates how a system call jump table is modified in accordance with an embodiment of the present invention.

FIG. 4 is a flow chart illustrating the process of configuring and running the auditing system in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

The following description is presented to enable any person skilled in the art to make and use the invention, and is provided in the context of a particular application and its requirements. Various modifications to the disclosed embodiments will be readily apparent to those skilled in the art, and the general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the present invention. Thus, the present invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

The data structures and code described in this detailed description are typically stored on a computer readable storage medium, which may be any device or medium that can store code and/or data for use by a computer system. This includes, but is not limited to, magnetic and optical storage devices such as disk drives, magnetic tape, CDs (compact discs) and DVDs (digital video discs), and computer instruction signals embodied in a transmission medium (with or without a carrier wave upon which the signals are modulated). For example, the transmission medium may include a communications network, such as the Internet.

Computer System

FIG. 1 illustrates a computer system 102 in accordance with an embodiment of the present invention. Computer system 102 can generally include any type of computer system, including, but not limited to, a computer system based on a microprocessor, a mainframe computer, a digital signal processor, a personal organizer, a device controller, and a computational engine within an appliance.

Computer system 102 is coupled to database 104. Database 104 can generally include any type of system for storing data in non-volatile storage. This includes, but is not limited to, systems based upon magnetic, optical, and magneto-optical storage devices, as well as storage devices based on flash memory and/or battery-backed up memory. Database 104 contains audit log 105 for recording auditing information for intrusion detection purposes in accordance with an embodiment of the present invention.

Computer system 102 is also coupled to remote computer system 118 through network 116. Network 116 can include any type of wire or wireless communication channel capable of coupling together computing nodes. This

includes, but is not limited to, a local area network, a wide area network, or a combination of networks. In one embodiment of the present invention, network 116 includes the Internet.

Remote computer system 118 can include any entity that is capable of transmitting suspect code 108 across network 116 into computer system 102.

Suspect code 108 may additionally be introduced into computer system 102 by encoding suspect code 108 on a computer-readable storage medium, such as disk 120, and introducing disk 120 into computer system 102. Note that disk 120 can generally include any type of computer-readable storage medium, such as a magnetic disk, a magnetic tape and a CD-ROM.

Also note that suspect code 108 may also be introduced into computer system 102 through other communications mechanisms.

During operation, computer system 102 executes suspect code 108 as well as intrusion detection system (IDS) 106. During execution, suspect code 108 makes a number of system calls through system call interface 112. These system calls are intercepted by agile auditor 110, which causes target attributes from the system calls to be recorded within audit log 105 upon detection of an auditing criterion.

Agile auditor 110 can generally include any type of mechanism for auditing system calls generated by suspect code 108. Note that agile auditor 110 makes use of loadable kernel module 122, which contains code that records specified attributes for specific system calls upon the occurrence of specific auditing criteria.

Agile auditor 110 in turn makes system calls through real system call interface 114 to access system call code 115. Note that real system call interface 114 is a pre-existing system call interface for operating system 113. Agile auditor 110 and system call interface 112 are layered on top of real system call interface

114 in order to intercept system calls generated by suspect code 108.

Process of Configuring Auditing System

FIG. 2 illustrates the process if configuring an auditing system in accordance with an embodiment of the present invention. The system starts with an audit specification 202 that specifies specific attributes to be recorded for specific system calls upon the occurrence of specific auditing criteria.

Audit specification 202 feeds through a special audit specification compiler 204, which converts audit specification 202 into auditing code to implement audit specification. This auditing code is packaged into a loadable kernel module 122, which is loaded into operating system 113 within computer system 102.

System Call Jump Table

FIG. 3 illustrates how system call jump table 302 is modified in accordance with an embodiment of the present invention. System call jump table 302 includes a number of entries that specify the location of corresponding system call functions. For example, entry 304 within system call jump table 302 would normally point to real system call code 308. However, during the process of linking loadable kernel module 122 into operating system 113, entry 304 is modified to point to code 306 within loadable kernel module 122.

Code 306 first records a target attribute if a specific auditing criterion is satisfied. For example, upon detecting a write to a password file, code 306 may record all data that is written to the password file.

Note that the target attribute can generally include any information related to the system call, including an argument of the system call, a parameter related to a process making the system call (such as a process ID, an effective user ID, a user

ID, a group ID, an effective group ID, a parent process ID, a session ID and a pathname for the process), data read during the system call, data written during the system call, a parameter related to a file involved in the system call (such as a permission mode, an inode number, a device ID, a time of creation, an owner user ID and a file type) or a parameter related to a network communication involved in the system call (such as an IP address or port number).

Also note that the auditing criterion can generally include any specifier for a condition associated with a system call, including a user identifier for a process that is making the system call, an identifier for an application program from which the system call is being made or an identifier for a file being accessed by the system call. Note that the condition is satisfied if a currently used identifier matches the specified identifier. For example, if the identifier specifies a password file, if the password file is being currently accessed, the condition is satisfied.

Next code 306 calls the real underlying system call through real system call interface 114.

After the real system call returns, code 306 can record another target attribute in response to detecting another auditing criterion. This capability is useful for recording the result of the real system call.

Process of Configuring and Running Auditing System

FIG. 4 is a flow chart illustrating the process of configuring and running the auditing system in accordance with an embodiment of the present invention. The system starts by receiving audit specification 202 (step 402). In one embodiment of the present invention, audit specification 202 is received from either a human user of the auditing system, or from an intrusion detection mechanism that automatically generates audit specification 202.

Audit specification 202 is compiled using audit specification compiler 204 to produce loadable kernel module 122 (step 404). Next, loadable kernel module 122 is inserted into the kernel of operating system 113 (step 406).

This loading process involves modifying system call jump table 302 (from FIG. 3) so that code 306 is accessed during a reference to a specified system call (step 408). This causes the specified system call to record the target attribute if a specified auditing criterion is satisfied.

Next, suspect code 108 is executed. This causes agile auditor 110 to record specified target attributes during specified system calls to audit log 105 (step 410). Note that producing audit log 105 can involve filtering the target attribute to reduce an amount of data stored in audit log 105. This filtering may also involve determining a characteristic of the target attribute and storing the characteristic instead of the target attribute. For example, the auditing system may determine that data read during a system call is binary executable code. In this case, the characteristic "binary" can then be stored in audit log 105 instead of storing the binary executable code itself.

Next, the system examines audit log 105 for intrusion detection purposes (step 412). Note that in general any type of intrusion detection mechanism can be used with the present invention. Hence, the details of the intrusion detection mechanism will not be discussed further in this specification.

Also note that the present invention can be dynamically configured to gather specific information for specific intrusion detection mechanisms. Upon detecting an event during the auditing process (step 414), the system can dynamically adjust itself in response to the event (step 416). For example, upon detecting retrieval of data from a remote server, the system can record all reads and writes involving the process that retrieved the data.

Note that by selectively recording target attributes, the present invention can reduce the amount of data that is recorded during the auditing process. This makes it practical to record data that is read or written during system calls without overwhelming the storage capacity, processing power and/or data transfer bandwidth of a computer system.

The foregoing descriptions of embodiments of the invention have been presented for purposes of illustration and description only. They are not intended to be exhaustive or to limit the present invention to the forms disclosed. Accordingly, many modifications and variations will be apparent to practitioners skilled in the art. Additionally, the above disclosure is not intended to limit the present invention. The scope of the present invention is defined by the appended claims.

What Is Claimed Is:

1. A method for providing content-based intrusion detection for a computer system by using an agile kernel-based auditing system, comprising:

receiving an audit specification;

wherein the audit specification specifies at least one target attribute to be recorded from a set of possible target attributes during an auditing process by the auditing system;

wherein the audit specification also specifies at least one auditing criterion that triggers recording of the at least one target attribute during the auditing process;

configuring the auditing system to record the at least one target attribute in response to detecting the at least one auditing criterion;

running the auditing system to produce an audit log by recording the at least one target attribute in response to detecting the at least one auditing criterion; and

examining the audit log to detect patterns for intrusion detection purposes.

2. The method of claim 1, further comprising:

detecting an event during the auditing process; and

in response to detecting the event, dynamically adjusting the auditing system during the auditing process to change the at least one auditing criterion and/or the at least one target attribute for subsequent operation of the auditing system.

3. The method of claim 1, wherein the auditing system is configured to modify a system call jump table to cause at least one selected system call to

execute code that causes the at least one target attribute to be recorded in response to detecting the at least one auditing criterion.

4. The method of claim 1, wherein the at least one target attribute can include:

an argument from a system call;

a parameter of a process making the system call;

data read during the system call;

data written during the system call;

a parameter of a file involved in the system call; and

a parameter relating to a network communication involved in the system call.

5. The method of claim 1, wherein configuring the auditing system to record the at least one target attribute involves:

compiling the audit specification to produce a kernel module;

loading the kernel module into a kernel of an operating system of the computer system; and

linking code from within the kernel module into system calls within the operating system.

6. The method of claim 1, wherein the at least one auditing criterion can include:

a user identifier for a process that is making a system call;

an identifier for an application program from which the system call is being made; and

an identifier for a file being accessed by the system call.

7. The method of claim 1, wherein producing the audit log involves filtering the at least one target attribute to reduce an amount of data stored in the audit log.

8. The method of claim 1, wherein producing the audit log involves:

determining at least one characteristic of the at least one target attribute; and

recording the at least one characteristic in the audit log.

9. The method of claim 1, wherein the audit specification is received from one of:

a user of the auditing system; and

an intrusion detection mechanism.

10. A computer-readable storage medium storing instructions that when executed by a computer cause the computer to perform a method for providing content-based intrusion detection for a computer system by using an agile kernel-based auditing system, the method comprising:

receiving an audit specification;

wherein the audit specification specifies at least one target attribute to be recorded from a set of possible target attributes during an auditing process by the auditing system;

wherein the audit specification also specifies at least one auditing criterion that triggers recording of the at least one target attribute during the auditing process;

configuring the auditing system to record the at least one target attribute in response to detecting the at least one auditing criterion in response to detecting the at least one auditing criterion;

running the auditing system to produce an audit log by recording the at least one target attribute; and

examining the audit log to detect patterns for intrusion detection purposes.

11. The computer-readable storage medium of claim 10, wherein the method further comprises:

detecting an event during the auditing process; and

in response to detecting the event, dynamically adjusting the auditing system during the auditing process to change the at least one auditing criterion and/or the at least one target attribute for subsequent operation of the auditing system.

12. The computer-readable storage medium of claim 10, wherein the auditing system is configured to modify a system call jump table to cause at least one selected system call to execute code that causes the at least one target attribute to be recorded in response to detecting the at least one auditing criterion.

13. The computer-readable storage medium of claim 10, wherein the at least one target attribute can include:

an argument from a system call;

a parameter of a process making the system call;

data read during the system call;

data written during the system call;

a parameter of a file involved in the system call; and

a parameter relating to a network communication involved in the system call.

14. The computer-readable storage medium of claim 10, wherein configuring the auditing system to record the at least one target attribute involves:

compiling the audit specification to produce a kernel module;

loading the kernel module into a kernel of an operating system of the computer system; and

linking code from within the kernel module into system calls within the operating system.

15. The computer-readable storage medium of claim 10, wherein the at least one auditing criterion can include:

a user identifier for a process that is making a system call;

an identifier for an application program from which the system call is being made; and

an identifier for a file being accessed by the system call.

16. The computer-readable storage medium of claim 10, wherein producing the audit log involves filtering the at least one target attribute to reduce an amount of data stored in the audit log.

17. The computer-readable storage medium of claim 10, wherein producing the audit log involves:

determining at least one characteristic of the at least one target attribute; and

recording the at least one characteristic in the audit log.

18. The computer-readable storage medium of claim 10, wherein the audit specification is received from one of:

a user of the auditing system; and

an intrusion detection mechanism.

19. A apparatus for providing content-based intrusion detection for a computer system by using an agile kernel-based auditing mechanism, comprising:

an auditing mechanism that is configured to audit system calls;

a receiving mechanism that is configured to receive an audit specification;

wherein the audit specification specifies at least one target attribute to be recorded from a set of possible target attributes during an auditing process by the auditing mechanism;

wherein the audit specification also specifies at least one auditing criterion that triggers recording of the at least one target attribute during the auditing process;

an initialization mechanism that configures the auditing mechanism to record the at least one target attribute in response to detecting the at least one auditing criterion;

wherein the auditing mechanism is configured to produce an audit log by recording the at least one target attribute in response to detecting the at least one auditing criterion; and

an intrusion detection mechanism that is configured to examine the audit log to detect patterns for intrusion detection purposes.

20. The apparatus of claim 19, wherein the initialization mechanism is further configured to:

detect an event during the auditing process; and

in response to detecting the event, to dynamically adjust the auditing mechanism during the auditing process to change the at least one auditing criterion and/or the at least one target attribute for subsequent operation of the auditing mechanism.

21. The apparatus of claim 19, wherein the auditing mechanism is configured to modify a system call jump table to cause at least one selected system call to execute code that causes the at least one target attribute to be recorded in response to detecting the at least one auditing criterion.

22. The apparatus of claim 19, wherein the at least one target attribute can include:

an argument from a system call;

a parameter of a process making the system call;

data read during the system call;

data written during the system call;

a parameter of a file involved in the system call; and

a parameter relating to a network communication involved in the system call.

23. The apparatus of claim 19, wherein the auditing mechanism is configured to:

compile the audit specification to produce a kernel module;

load the kernel module into a kernel of an operating system of the computer system; and to

link code from within the kernel module into system calls within the operating system.

24. The apparatus of claim 19, wherein the at least one auditing criterion can include:

a user identifier for a process that is making a system call;

an identifier for an application program from which the system call is being made; and

an identifier for a file being accessed by the system call.

25. The apparatus of claim 19, wherein the auditing mechanism is configured to produce the audit log by filtering the at least one target attribute to reduce an amount of data stored in the audit log.

26. The apparatus of claim 19, wherein the auditing mechanism is configured to produce the audit log by:

determining at least one characteristic of the at least one target attribute; and

recording the at least one characteristic in the audit log.

27. The apparatus of claim 19, wherein the audit specification is received from one of:

a user of the auditing mechanism; and

the intrusion detection mechanism.

METHOD AND APPARATUS FOR CONTENT-BASED INTRUSION DETECTION USING AN AGILE KERNEL-BASED AUDITOR

ABSTRACT

One embodiment of the present invention provides content-based intrusion detection for a computer system by using an agile kernel-based auditing system. This auditing system operates by receiving an audit specification that specifies target attributes to be recorded during an auditing process. The audit specification also specifies an auditing criterion that triggers recording of the target attributes. Upon receiving the audit specification, the auditing system is configured to record the target attributes during system calls whenever the auditing criterion is satisfied. Next, an application program is monitored by the auditing system to produce an audit log containing the recorded target attributes. This audit log is examined in order to detect patterns for intrusion detection purposes. In one embodiment of the present invention, configuring the auditing system involves compiling the audit specification to produce a kernel module, and then loading the kernel module into a kernel of an operating system. It also involves linking code from within the kernel module into system calls within the operating system. In one embodiment of the present invention, in response to detecting an event during the auditing process, the system dynamically adjusts the auditing system to change the auditing criterion and/or the target attributes for subsequent operation of the auditing system.

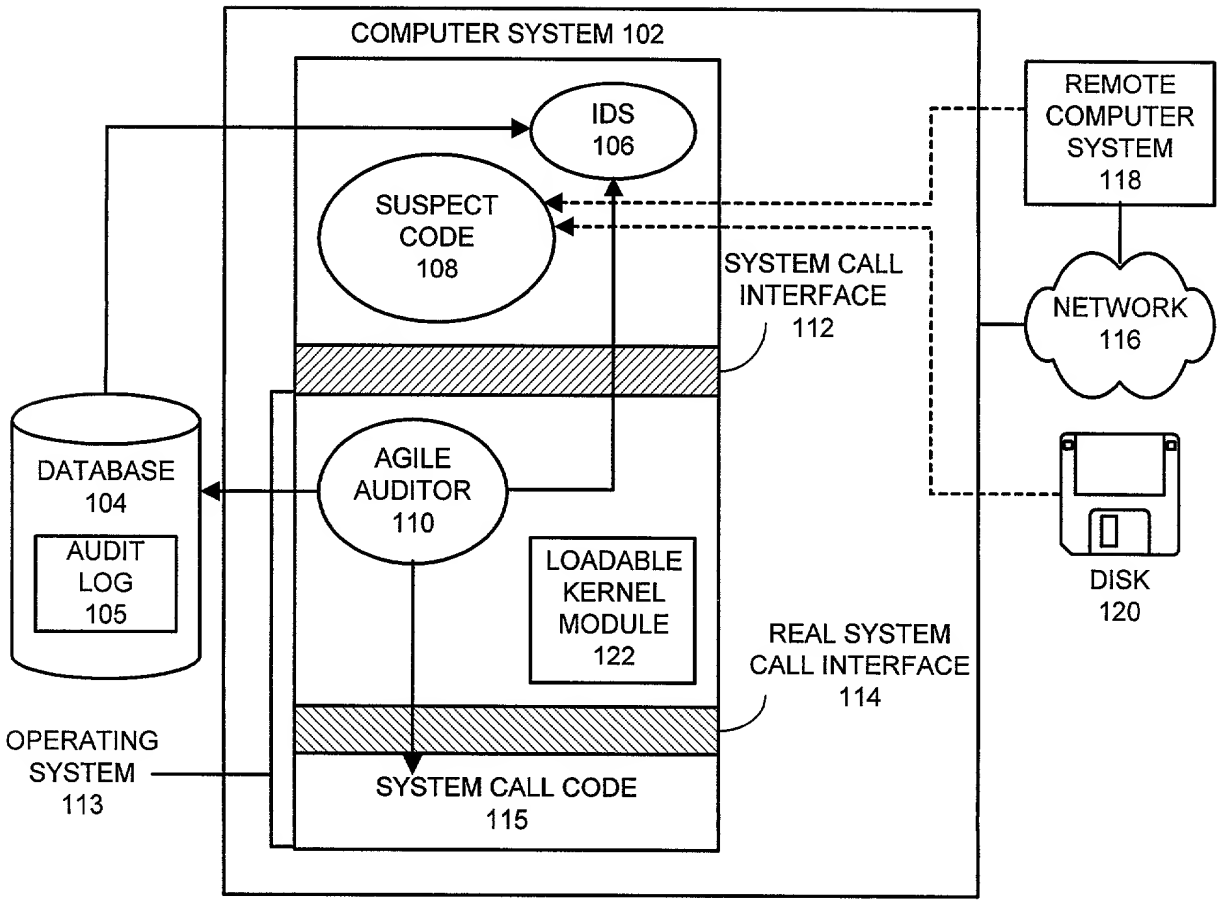
COMPUTER SYSTEM 102
IDS
106
SUSPECT
CODE
108
SYSTEM CALL
INTERFACE
112
REMOTE
COMPUTER
SYSTEM
118
NETWORK
116
DISK
120
DATABASE
104
AUDIT
LOG
105
AGILE
AUDITOR
110
LOADABLE
KERNEL
MODULE
122
REAL SYSTEM
CALL INTERFACE
114
OPERATING
SYSTEM
113
SYSTEM CALL CODE
115

FIG. 1

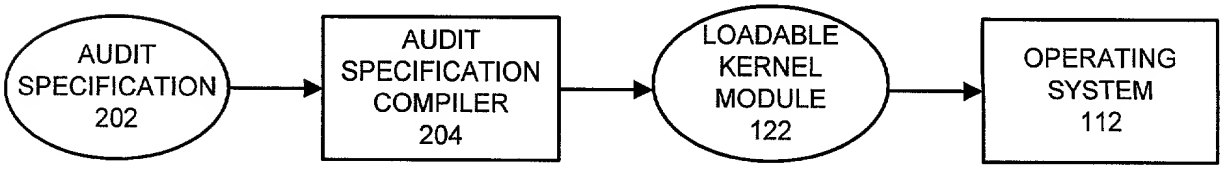
AUDIT
SPECIFICATION
202
AUDIT
SPECIFICATION
COMPILER
204
LOADABLE
KERNEL
MODULE
122
OPERATING
SYSTEM
112

FIG. 2

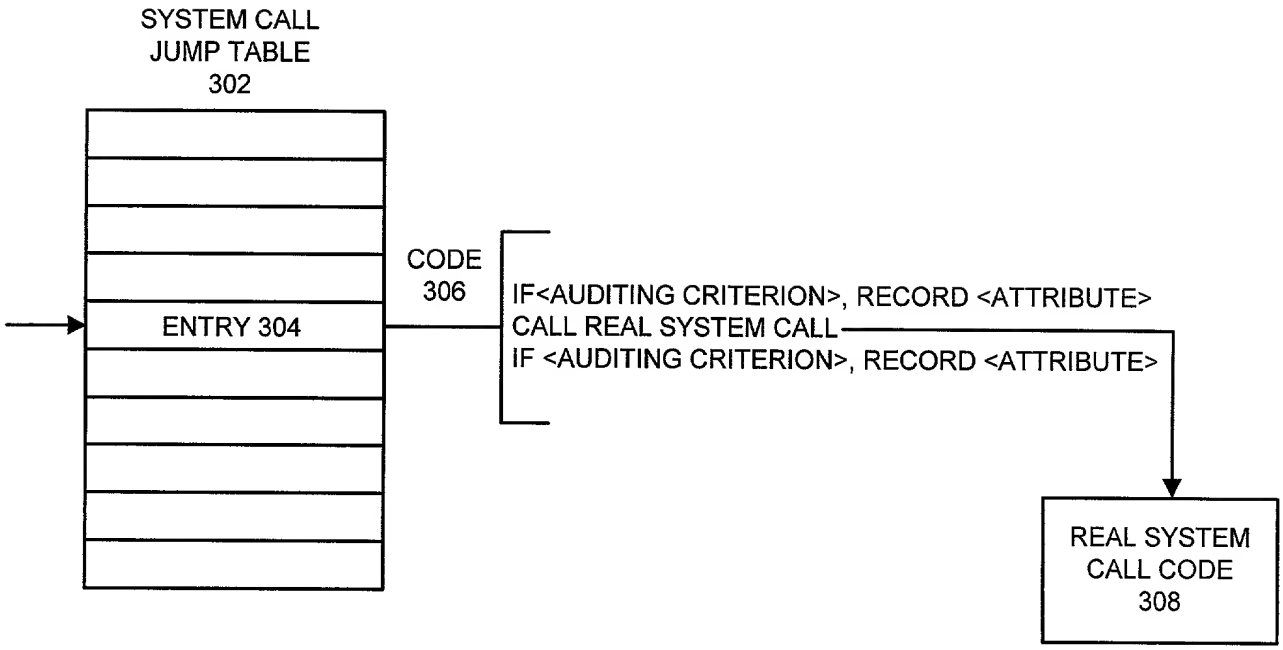
SYSTEM CALL
JUMP TABLE
302
ENTRY 304
CODE
306
IF<AUDITING CRITERION>, RECORD <ATTRIBUTE>
CALL REAL SYSTEM CALL
IF <AUDITING CRITERION>, RECORD <ATTRIBUTE>
REAL SYSTEM
CALL CODE
308

FIG. 3

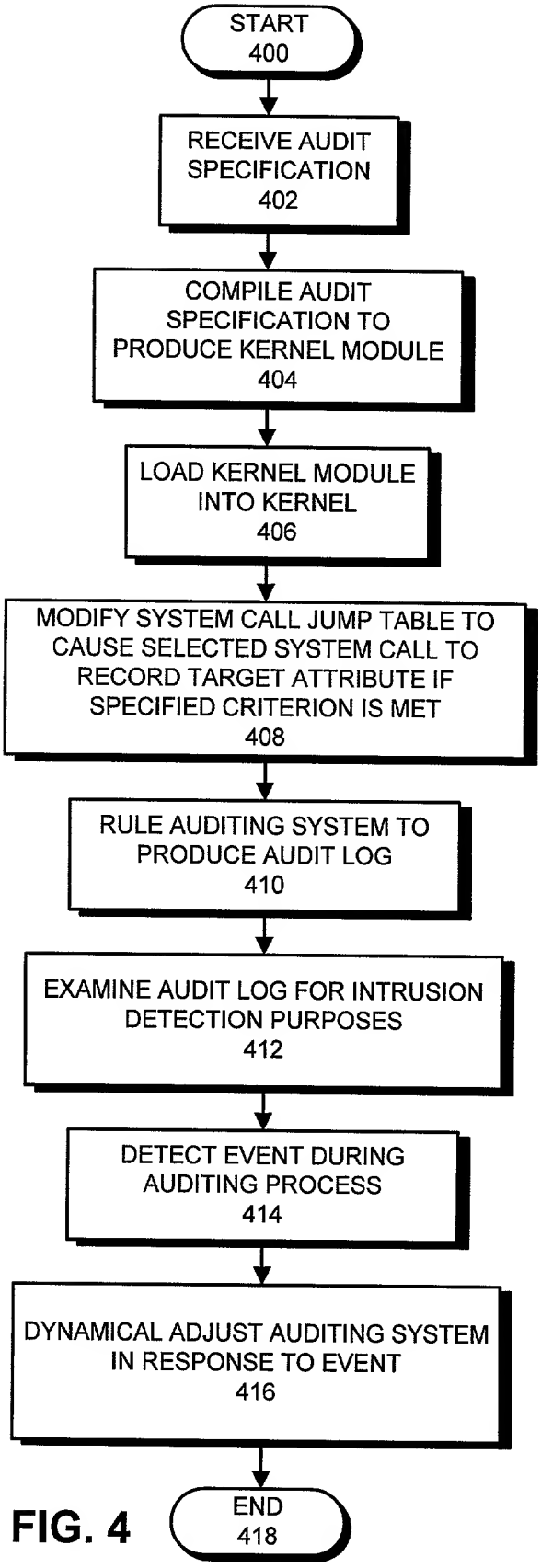
START
400
RECEIVE AUDIT SPECIFICATION
402
COMPILE AUDIT SPECIFICATION TO PRODUCE KERNEL MODULE
404
LOAD KERNEL MODULE INTO KERNEL
406
MODIFY SYSTEM CALL JUMP TABLE TO CAUSE SELECTED SYSTEM CALL TO RECORD TARGET ATTRIBUTE IF SPECIFIED CRITERION IS MET
408
RULE AUDITING SYSTEM TO PRODUCE AUDIT LOG
410
EXAMINE AUDIT LOG FOR INTRUSION DETECTION PURPOSES
412
DETECT EVENT DURING AUDITING PROCESS
414
DYNAMICAL ADJUST AUDITING SYSTEM IN RESPONSE TO EVENT
416
END
418

FIG. 4

Attorney Docket No. NA00-02401

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below by my name;

I believe I am the original, first and sole inventor, if only one name is listed below, or an original, first and joint inventor if multiple names are listed below, of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND APPARATUS FOR CONTENT-BASED INTRUSION DETECTION USING AN AGILE KERNEL-BASED AUDITOR

for which a patent application:

☒ is attached hereto.

☐ was filed in the United States on _ as Application No. _;

☐ with amendment(s) filed on _____ *(if applicable)*.

I hereby state that I have reviewed and understand the contents of the application identified above, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information known to me to be material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56, which states in relevant part:

> Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section . The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office....

I hereby claim foreign priority benefits under Title 35, United States Code, §119(a)-(d), of any foreign application(s) for patent or inventor's certificate as indicated below and have also identified below any foreign application for patent or inventor's certificate on this invention having a filing date before that of the application on which priority is claimed:

EARLIEST FOREIGN APPLICATION(S), IF ANY, FILED PRIOR TO THE FILING DATE OF THE APPLICATION			
APPLICATION NUMBER	COUNTRY	DATE OF FILING (Day, Month, Year)	PRIORITY CLAIMED
			YES ☐ NO ☐

I hereby claim the benefit under Title 35, United States Code, §119(e), of any United States provisional application(s) listed below:

APPLICATION NUMBER	DATE OF FILING

I hereby claim the benefit under Title 35, United States Code, §120, of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information that is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56, which became available between the filing date of the prior application and the national or PCT international filing date of this application:

APPLICATION NUMBER	DATE OF FILING	STATUS		
		PATENTED	PENDING	ABANDONED

I hereby appoint Daniel E. Vaughan (Reg. No. 42,199) and A. Richard Park (Reg. No. 41,241) to prosecute this application

and transact all business in the Patent and Trademark Office connected therewith, and to file, prosecute and transact all business in connection with international applications directed to said invention.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Title 18, United States Code, §1001, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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